University of Wisconsin-Madison

Distributed Resources to Meet Demands of High-Value Power

Goals

High-value power is uninterrupted power with tightly controlled voltage deviations that meets the stringent requirements of critical and sensitive loads. It is efficient, environmentally friendly, and cost-competitive.

The Wisconsin Power Electronics Research Center (WisPERC) of the University of Wisconsin-Madison is conducting research and development to develop, model, and demonstrate operation and control features for inverter-based distributed resources (DR) in a microgrid that enables high-value power. Microgrids that incorporate a cluster of DR could capture the benefits of byproduct heat along with the high-value, or premium, power and provide grid support, deferred distribution cost, and coordinated demand-side management.

WisPERC's microgrid test hardware

For high-value power, the quality of voltage and current are carefully managed so that critical loads are not affected by abnormal events such as voltage imbalances, power sags, swells, harmonics, and short-term outages. WisPERC researchers are modeling and simulating these events to identify how DR can provide premium power and verifying their results in a laboratory-scale, multiple-inverter microgrid test bed. In particular, the WisPERC project models and tests a microgrid of interconnected DR that can switch from grid connection to an intentional island operation while continuously providing high-value power in the presence of grid disturbances.

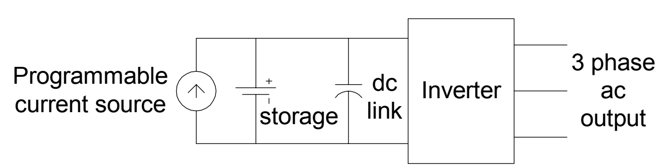
Achievements include:

- Investigation of energy storage requirements for DR systems resulting in a design procedure, functional model, and simulation for deep-cycle lead-acid batteries to manage sudden changes in load demand
- Modeling of two emulated DR to respond to load changes under a variety of load profiles to define improved control and protection methodologies
- Improvements to the microgrid test bed to implement control strategies and experimentally verify theoretical analyses and computer simulations
- Improved capability for rapid disconnection and reconnection, electronic synchronizing circuitry
- Modeling performance of a two-inverter microgrid in an office/warehouse case study
- Modeling a control strategy for DR in a microgrid for various grid-connected and island operations
- Design of a DR controller using a novel, complex control technique for seamless reconnection.

Results

Systems Approach

WisPERC uses a generic model of a DR to study the operation of a variety of devices, including wind turbines, microturbines, and fuel cells. Technical objectives include modeling a control and operation strategy to manage the DR in the microgrid. Detailed analytical modeling and computer simulations are then verified with actual hardware in the test lab.

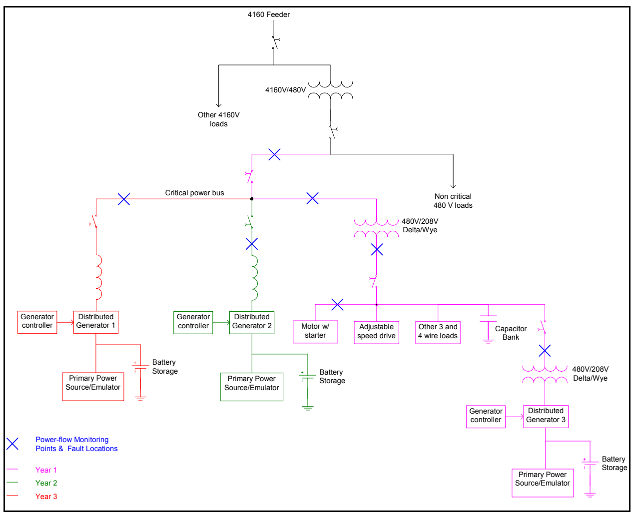


Block diagram of model distributed resource system

Laboratory-Scale Microgrid

To physically study and benchmark the DR components, verify the operation of the proposed models and simulations, and implement various control strategies, WisPERC has developed a laboratory-scale microgrid test bed. During Phase 1, the first DR was commissioned to run standalone and a programmable DC power source implemented. During Phase 2, the laboratory system was expanded to include two interconnected microturbines. During Phase 3, a third microturbine will be added to the model and test bed to evaluate test approaches in a multiple-inverter microgrid.

Researchers test simulations in the laboratory-scale microgrid, and these experimental results are used to further refine the control algorithms and iterate on the best possible approach to achieve the desired high-value performance objectives for the DR system.



One-line schematic of the laboratory-scale microgrid

The system has been designed to provide maximum flexibility and variety of loads to study the operation of the systems under various operating scenarios. The experimental system features:

- A directly interfaced DG system
- A transformer-coupled DG system
- Test island operation
- Induction motor loads
- Adjustable-speed drive loads
- Four wire systems
- Single-phase loads
- Digital signal processing platform
- AC-side capacitor banks.

Case Study

Researchers modeled a two-microturbine sytem to evaluate a case study for an office/warehouse, simulating both balanced and unbalanced loads. For grid-connected operation with balanced loads, both DR regulate the power in the microgrid at a constant value. During standalone operation, the units switch to a power-frequency frequency to ensure the units match the power missing from the grid.

As modeled, even under unbalanced loads, the pulse-width modulated inverter in a DR can provide uninterrupted power, improved power quality, and energy conversion at reasonable cost. It can also compensate for load current harmonics. The design of the regulator permits controlling the inverter current during faults, which is implemented using a digital signal processing system.

Testing of a laboratory-scale microgrid indicates some issues when implementing the controllers. Investigations are continuing to address practical implementation of the modeled results.

Publications

Venkataramanan, G.; Illindala, M.S.; Houle, C.; Lasseter, R.H. "Hardware Development of a Laboratory-Scale Microgrid Phase 1: Single Inverter in Island Mode Operation, Base Year Report: December 2000-November 2001." NREL/SR-560-32527. November 2002.

Illindala, M.; Piagi, P.; Zhang, H.; Venkataramanan, G.; Lasseter, R. "Hardware Development of Laboratory-Scale Microgrid Phase 2: Operation and Control of a Two-Inverter Microgrid." NREL/SR-560-35059.

Publications are available on the NREL publications database, http://www.nrel.gov/publications/.

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